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Prediction of Radar Pulse Envelope Distortion due to Tropospheric Propagation

Marina Ozerova

DSTO-TN-0125

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Marina Ozerova

Electronic Warfare Division Electronics and Surveillance Research Laboratory

DSTO-TN-0125

ABSTRACT

This project is a part of research into the detection of radar signals at ranges well beyond the horizon by exploiting the effect of tropospheric scattering. A result of this work is a program written in C language which enables the distortion of the envelope of a given radar pulse, which occurs as a result of propagating over any path by tropospheric scattering, to be predicted.

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EXECUTIVE SUMMARY

The objective of the work described in this report is to investigate the possibilities of detecting radar transmissions from very long range by means of tropospheric scatttering.

The propagation of radio waves via the troposphere occurs as a result of a scattering mechanism which takes place in the volume of the tropospheric medium where the beams of the transmitting and receiving antennas overlap.

Radar signals which propagate via the troposphere will have a distorted pulse envelope shape due to the difference in the transit time between the shortest and longest paths from the transmitter to the receiver via the extremities of the scattering volume. The extent of the distortion will depend on the pulse duration compared to the time difference between propagation via the longest and shortest paths.

The main objective of the work described in this report was to predict the distortion of the pulse envelope shape of radar signals after propagation via the troposphere. In order to optimise the detection of tropospheric scattered radar signals it is desirable to be able to predict this distortion to enable a better matched filter to be designed.

The procedure adopted is to assume that the variations to the pulse shape result from the spatial distribution of the scattering and the scattering mechanism is equivalent to the reflection of the signal from a large number of point reflectors randomly distributed within the scattering volume.

Author

Marina Ozerova

Wide Area Surveillance Division

Marina Ozerova recently joined DSTO as a Professional Officer Class 1 in Wide Area Surveillance Division although the work described in this report was done in Electronic Warfare Division prior to her appointment. Marina was born in Russia and graduated from the Physics Faculty of Nizhny Novgorod State University in 1987. She defended her project on low temperature deposition of semiconductors using high frequency plasma thermodecomposition of $Cd(CH_3)_2$ and $Te(CH_3)_2$ metal organic compounds widely used in infra-red detectors. emigrated to Australia in 1993 and has since become an Australian Citizen. After arriving in Australia she undertook a number of work experience jobs to help adapt to the Australian work environment and to improve her command of English. Work experience included working as a Physicist for the Department of Mines and Energy, the Radiation Protection Branch of the S.A. Health Commission and, finally, with Electronic Warfare Division of the DSTO.

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1. Introduction

The problem of scattering of electromagnetic waves in the troposphere attracts considerable attention from scientists and engineers. The phenomenon related to long-range atmospheric propagation of short waves beyond the limits of the "radio horizon" is known to be one of the least developed subjects of this kind.

Thus, the propagation of radio waves via the troposphere occurs as a result of the poorly understood mechanism of scattering which takes place in the volume of space where the beams of the transmitting and receiving antennas overlap.

The goal of this project was not to dwell on all the numerous problems associated with the use of radio scattering for the purpose of long range communication. Instead, the main objective of the current project were to predict the distortion of the pulse envelope shape of radar signals after propagation via the troposphere. The ability to predict the pulse envelope will enable a better matched filter to be designed for detecting the signals.

Radar signals which propagate via the troposphere will have a distorted pulse envelope shape if the difference in the transit time between the shortest and longest paths from the transmitter to the receiver, via the extremities of the scattering volume, is comparable with the pulse duration and in most instances this will be the case. In order to optimise the detection of tropospheric scattered radar signals it is desirable to be able to predict the pulse envelope distortion that will occur.

The area of our interest is in estimating the variations to the pulse shape and since this envelope shape distortion will not result from the scattering mechanism itself but from the spatial distribution of the scattering, it should be possible to calculate the likely effect by assuming the scattering mechanism is equivalent to the reflection of the signal from a large number of point reflectors distributed within the scattering volume.

As can be seen from Figure 1, if the elevation and azimuth beam shapes of the transmitting and receiving antennas are known, then we could calculate the signal strength and relative phase at the receiver for some nominal transmitter power and a nominal cross section reflector situated at any given point within the scattering volume. It is also possible to calculate the transit time between transmission and reception of this reflected signal.

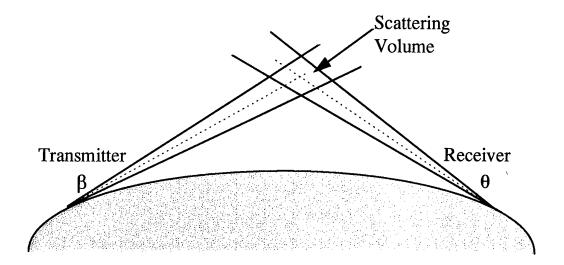


Figure 1: Scattering volume.

It is reasonable to assume that the envelope shape of the signal reflected from a point reflector will be identical to the envelope shape of the transmitted signal. Applying this condition to a large number of identical point reflectors distributed throughout the scattering volume and summing all the individual signals, taking into account the transit time delay of the amplitude envelope and the phase of each signal, then it should be possible to construct the probable amplitude profile of a troposcattered signal for any given transmitted signal envelope shape.

In this project we will not take into account the scattering phenomenon itself, i.e. attenuation, depolarisation and volume scattering effects leading to troposcatter losses. Only a brief theoretical introduction of these effects will be given. Results of computations of troposcatter losses employing known empirical approaches, i.e. NBS, Yeh, Rider etc. were presented in [5].

However, it is believed that the results of the current project which considers the change in the envelope shape due to spatial distribution of the reflectors inside the scattering volume, could be coupled with the results of earlier work [5] in future tasks in order to estimate the combined effect.

2. Radio scattering in the troposphere

This section is a brief introduction and overview of the theory of propagation of radio waves via the troposphere.

2.1 Interaction processes in the troposphere

There are a number of possible mechanisms whereby radiowaves can interact with the lower atmosphere to produce scattering, these include:

- absorption and dispersion in atmospheric gases (oxygen, water vapour and minor constituents);
- scattering from atmospheric turbulence and scintillation;
- scattering and absorption in populations of hydrometeors (including anisotropic effects, forward scatter, back scatter, and scattering at arbitrary angles);
- scattering and absorption in sand and dust particle populations;
- refraction and reflection in stable atmospheric layers;
- thermal emission from hydrometeors and atmospheric gases.[1]

2.2 Theory of scattering and absorption

Attenuation, depolarization and volume scattering of radiowaves due to atmospheric particles are phenomena, which severely limit the performance of telecommunication systems.

Currently, mainly frequencies below 20 GHz are used by communication systems although the use of some millimetre wave frequencies where high absorption occurs has been advocated in the literature for short range secure links.

The basic theory describing different models for attenuation, depolarization and volume scattering is the theory for single-particle scattering. Particle scattering effects become more severe with higher frequencies. This is aggravated by the increasing effect of small particles, such as liquid droplets, which are present in great numbers in the atmosphere.

The problem of single and multiple scattering has been discussed by many authors. Some approaches have different interpretations of formulae and different ways to derive them.

Let us introduce just one model - single scattering approximation, which was described in Reference [3]. Here, the author considered a random medium illuminated by a transmitter. A part of the transmitted wave was scattered by the randomness of the medium and this scattered wave was detected by a receiver (Figure 2).

There was considered a volume δV in the random medium. It was assumed that the randomness of the medium was so slight that the wave incident on δV was almost equal to the incident wave in the absence of the random medium.

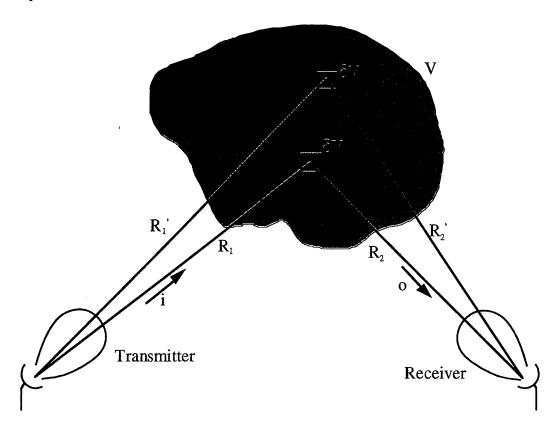


Figure 2: Geometry showing transmitter, receiver and random medium.

It was described by the amount of scattered power due to the random medium in δV in terms of the equivalent scattering cross section per unit volume $\sigma(0, I)$, then the received power P_r is given by the radar equation

$$P_r / P_t = \lambda^2 G_t(i) G_r(0) \sigma(0,i) \delta V / (4\pi)^2 R_1^2 R_2^2$$
, (1)

where Pt - transmitted power

 $G_{t_r}G_{r_r}$ - gain functions of the transmitter and receiver antennas in the directions of i and -0.

The basic scattering theory must be reviewed in order to find the limitations of its applicability to electromagnetic wave problems.

The theory of single and multiple scattering has been discussed in References [1, 2, 3, 4]. At this time, no references could be found that treat the basic scattering theory, as applied to communication systems, in a completely consistent way. This makes it difficult to understand the scattering theory [1].

2.3 Application of the theory of radio scattering in the troposphere to beam communication

Booker and Gordon [4] describe in their work the experiments made in the Caribbean Sea in 1945. The goal of these experiments was to explore the radio consequences of the evaporation-duct that exists at the ocean surface. As a result of this project it was discovered that, at any rate under some circumstances, field strength well beyond the horizon decreases with distance more slowly than could be expected on any existing theory. The wavelength used was 9 cm in this experiment. They found that the unexpectedly high field strengths obtained at long range on 9 cm were not due to duct propagation, and, accounting for the rather violent fading associated with them, it was suggested that a scattering mechanism was involved.

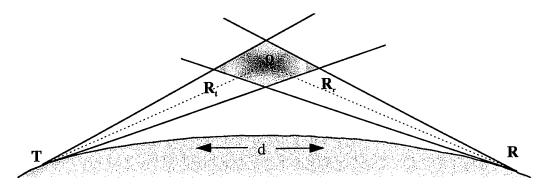


Figure 3: Antennas beams.

Booker and Gordon considered transmission from point T to point R at distance d round the curved surface of the earth by means of beamed antennas pointed more or less at each other as indicated in Figure 3. It was assumed that there were no ducts and that as far as ordinary reflection is concerned propagation was orthodox. It was supposed that both antennas were pointed horizontally at their respective locations, and that their axes lay in the vertical plane through T and R. For simplicity it was considered that the T and R antennas were identical. It was found that if the transmitter and receiver are omnidirectional, scattering is in general important from nearly the whole of the atmosphere above the horizons of both transmitter and receiver. However, in practice, both transmitter and receiver antennas usually have some directivity, and scattering is then important only in the region of atmosphere where the transmitting and receiving beams overlap.

As a result of the Caribbean experiments the following conclusions were made:

- 1. The modified scale of turbulence is expected to decrease with height above the earth's surface.
- 2. The theory of atmospheric scattering seems to predict a decrease of scattered field strength with distance that is too low to agree with the observation, in fact the scattering almost certainly decreases with height in most practical cases.
- 3. The height of the important scattering volume increases with the increase of distance between transmitter and receiver. An associated decrease of the modified scale of atmospheric turbulence would cause the scattering signal received to decrease more rapidly with the increase of range than for a uniformly turbulent atmosphere.
- 4. The same theory which is used for calculating the scattering signal at long distances may also be used in most cases for calculating the fading range at shorter distances.

3. Practical Procedure

First of all, it is necessary to emphasise that, because of the diverse nature of the problem, various approximations should be employed to obtain useful results. Therefore, some useful approximation techniques applicable to a variety of different situations will be presented in this project.

- 1. We will assume that the transmitter and receiver beam shapes are effectively rectangular.
- 2. We assign the transmitter to be at the origin (x = 1, y = 0) of a two dimensional coordinate system and the receiver to be on the x axis at a point that can be calculated from the great circle distance between the transmitter and receiver sites on the earth surface.
- 3. We assume both transmitter and receiver beam width to be the same.
- 4. Then we need to calculate the inclination of the transmitter and receiver antenna beams from the x axis, so that it is possible to calculate the x, y coordinates of the intersecting volume.
- Next, it is necessary to calculate the coordinates of an array of point reflectors
 which were initially assumed to be regularly spaced within the intersecting
 volume although this was later extended to include a uniform density random
 distribution.

- 6. For each of the points in the array we then calculate the path length between transmitter and receiver via each point and hence determine the transmit time for each point reflected signal. Because we are interested only in the differences, we subtract the mean transit time from the actual transit time to obtain the delta transit time.
- 7. Since the signal which is assumed to be reflected from the reflector at each point starts from the transmitter with the same phase, we must now calculate the relative RF phase of each reflected signal by dividing the path length via each point reflector by the free space wavelength of the RF signal and discarding the integer part.
- 8. Since we have initially chosen to assume a rectangular beam shape and that the path difference from each point reflector will only differ by a small percentage we now assume that all the signals reflected from the point reflectors have the same (unity) amplitude profile.

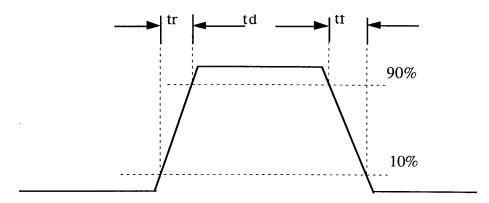


Figure 4: Pulse shape.

- 9. Now we define a suitable transmitter amplitude profile (pulse shape) by introducing three character-parameters, namely rise time t_r , fall time t_f , and duration t_d .
- 10. Finally, we produce a temporal plot of the resulting troposcattered waveform shape by doing a vector sum of all the point reflector outputs at each of a large number of time increments encompassing the pulse width and the range of delta transit time. The above is illustrated in Figure 4, and expressed more formally in the following equations:

$$\mathbf{A} = \sum (\mathbf{a}_i \cos \varphi_i + \mathbf{j} \ \mathbf{a}_i \sin \varphi_i), \tag{2}$$

where Λ - complex amplitude of the resulting envelope signal,

a_i - amplitude of initial envelope signal

 $j = \sqrt{-1}$

 $\varphi_i = (vl_i/c - Integer[vl_i/c]) 2\pi$

 ϕ_i - the phase of a signal reflected by point "i" from scattering volume,

v - RF frequency in MHz,

c - the light speed in vacuum in [km/s]'

l_i - the length of the path from the transmitter to receiver via point "i" in [km].

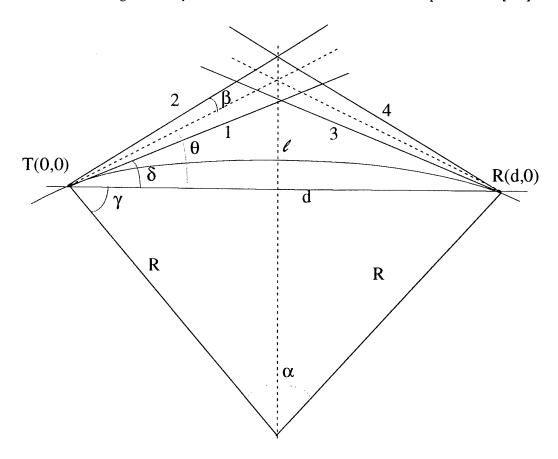


Figure 5: Geometry of beam intersection region.

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$$y = tan(\theta - \beta) x$$
 (equation for line 1) (3)

$$y = tan(\theta + \beta) x$$
 (equation for line 2) (4)

Assumption $\theta_1 = \theta_2 = \theta$

$$\beta_1 = \beta_2 = \beta$$

$$y = -\tan[\theta - \beta] x + b$$

$$0 = -\tan[\theta - \beta] d + b$$

d tan[θ - β] = b

$$y = dtan[\theta - \beta] - tan[\theta - \beta] x$$
, (equation for line 3) (5)

$$y = dtan[\theta + \beta] - tan[\theta + \beta] x$$
, (equation for line 4) (6)

$$tan[\theta - \beta] x = dtan[\theta - \beta] - tan[\theta - \beta] x , \qquad (7)$$

$$2\tan[\theta - \beta] x = d\tan[\theta - \beta] , \qquad (8)$$

$$\mathbf{x} = \mathbf{d/2} \quad , \tag{9}$$

where

R - effective radius of Earth (4/3 physical radius)

 β - the half beam width angle

1 - the distance between the transmitter and the receiver

 ϕ - the elevation angle of transmitter

n - number of points

 $1 = R\alpha$

$$d^2 = 2R^2 - 2R^2\cos\alpha = 2R(R - R\cos\alpha) , \qquad (10)$$

$$\mathbf{d} = \sqrt{2\mathbf{R}(\mathbf{R} - \mathbf{R}\mathbf{cos}\alpha)} \quad , \tag{11}$$

$$\gamma = (\pi - \alpha)/2 \quad , \tag{12}$$

$$\delta = \pi/2 - \gamma = \pi/2 - \pi/2 + \alpha/2 = \alpha/2 \quad , \tag{13}$$

$$\theta = \phi + \delta \quad , \tag{14}$$

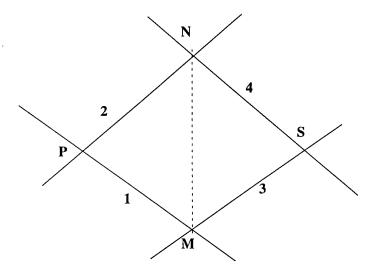


Figure 6: Scattering region.

We have equations for lines 1, 2, 3 and 4.

The ordinate of point N (y coordinate of N) is the maximum y value of the point to be distributed to the area.

The y coordinate of M is the minimum of y coordinate.

In the program the user specifies the numbers of rows, r and the spacing between the rows is Δ .

$$\Delta = \text{distance NM/r}$$
 , (15)

We know coordinates for the point N. N is specified by (x_N, y_N) . Take the y coordinate and decrease it's value by Δ , i.e. $y_N - \Delta$.

From Equation 2 substitute y_N - Δ for y and solve for x. This gives us the first point of the first row - point N.

To get the next point, the coordinate will be $(x_N + \Delta, y_N - \Delta)$. To find the maximum value of x put $y_N - \Delta$ into the equation 4 and solve x

While all this is being done, i.e. when each point is determined, we can at this time calculate the distance from transmitter to the receiver via the point. If the coordinates of the point are (x_P, y_P) then the distance from the transmitter to the receiver is

$$D = \sqrt{((x_P - x_T)^2 + (y_P - y_T)^2) + \sqrt{((x_P - x_R)^2 + (y_P - y_R)^2)}}, \qquad (16)$$

where x_T , y_T - coordinates of the transmitter,

 x_R , y_R - coordinates of the receiver,

which are $(x_T, y_T) = (0, 0)$

$$(x_R, y_R) = (d, 0)$$

4. Operation

The software was developed and runs on an IBM PC and is written in Borland, Turbo C++, version 1.00. The plotting macros require the use of Excel, version 5.0. This section describes how the software can be operated.

4.1 Installation

- pulse_d.exe, pulse_e.exe and pulse_r.exe files should be installed in c:\tc\bin
 directory
- pulse_d.xls, pulse_e.xls and pulse_r.xls files in any directory

4.2 Execution

To obtain a plot of the reflection point distribution:

- run pulse_d.exe in DOS;
- save output to a file called result_d.txt;
- when finished computations, open pulse_d.xls in Excel;
- run the program in "Execute" Sheet of pulse_d.xls workbook.

To obtain a table of data and a plot of the pulse after reflection from a uniform array of points:

- run pulse_e.exe in DOS;
- save output to a file called result_e.txt;
- when finished computations, open pulse_e.xls in Excel;
- run the program in "Execute" Sheet of pulse_e.xls workbook

To obtain a table of data and a plot of the pulse after reflection from a random array of points:

- run pulse_r.exe in DOS;
- save output to a file named result_r.txt;
- when finished computations, open pulse_r.xls in Excel;
- run the program in "Execute" Sheet of pulse_r.xls workbook.

Note that the programs pulse_e.xls and pulse_r.xls are identical except for the result file accessed and the labels on the resulting curves.

5. Conclusions

1. Software for computing the modulation envelope after propagation of a given radar signal via the troposphere accounting for the effect of spatial distribution of point reflectors in the scattering volume has been designed and tested.

At this stage, the propagation model is based on point reflectors in a single plane having vertical and horizontal directions with two types of distribution, namely, equidistantly spaced and randomly spaced with uniform density. Elevation angles of both transmitter and receiver were chosen to be equal, as well as their beamwidth angles.

2. The Turbo C++ executable file allows one to plot resulting graphs on the screen and save the data in text format.

A special program was designed in Visual Basic for Excel, which can automatically read the data from the text file generated in Turbo C++ and then plot the graph of envelope amplitude versus time.

[Note that, with hindsight, it would have been much easier for users if the whole program had been designed in Visual Basic. In this case, a computation could be realised by striking one key either on keyboard or on the mouse.]

- 3. Analysis of the results of computations of radar pulse envelope distortion due to tropospheric propagation have shown (Appendix 1, 2):
- pulse shape envelope does change significantly with beamwidth and elevation
 angle as might be expected since these parameters determine the distance between
 the shortest and longest paths via the reflection points;
- with uniform distribution there is some evidence of an interference pattern, which is smoothed out to a large degree with a random distribution.

- 4. The next steps in developing the current model describing radar pulse envelope distortion are envisaged to be:
- extending the analysis to a three dimensional case;
- introducing a vertical variation in the density of the random distribution of reflecting points to reflect the likely variation resulting from the change in density of the troposphere with height;
- introducing some randomness and vertical variation in the amplitude of the reflection from each reflecting point;
- since real radars that we might wish to detect frequently employ a vertical fan shaped (cosec²) beam, which is unlikely to be the best beam shape to use on the receiver, a new model is needed to take into account different values of beam width for the transmitting and receiving antennas.

6. Acknowledgments

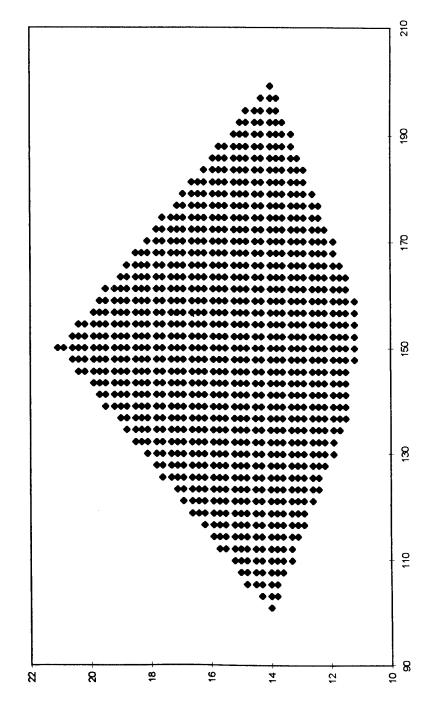
This work was done in Electronic Warfare Division under a Technical Support Services contract and the author is grateful for the access to the DSTO library and other facilities that were made available.

The author would like to gratefully acknowledge the contribution from Dr A.Kulessa for the help and advice, he gave me while I was doing this project. Also the author wishes to express her thanks to Mr R. Lindop for help received on the same topic.

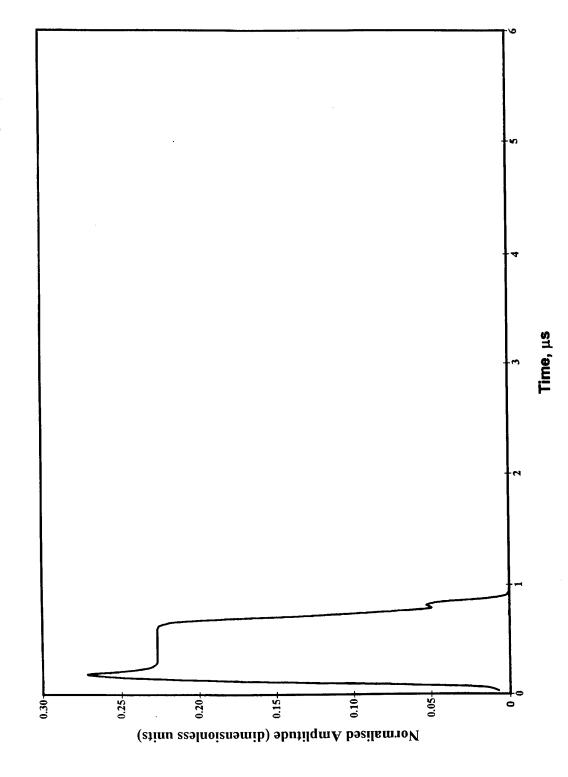
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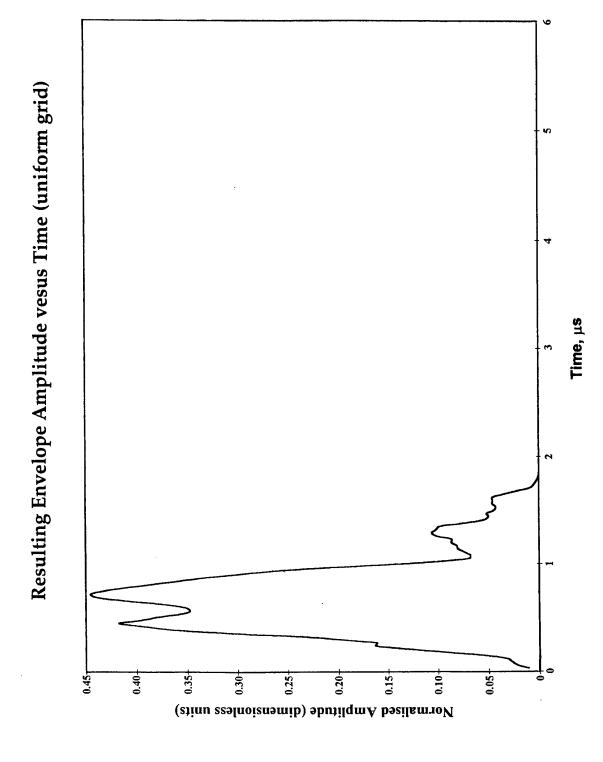


Resulting Envelope Amplitude vesus Time (uniform grid)



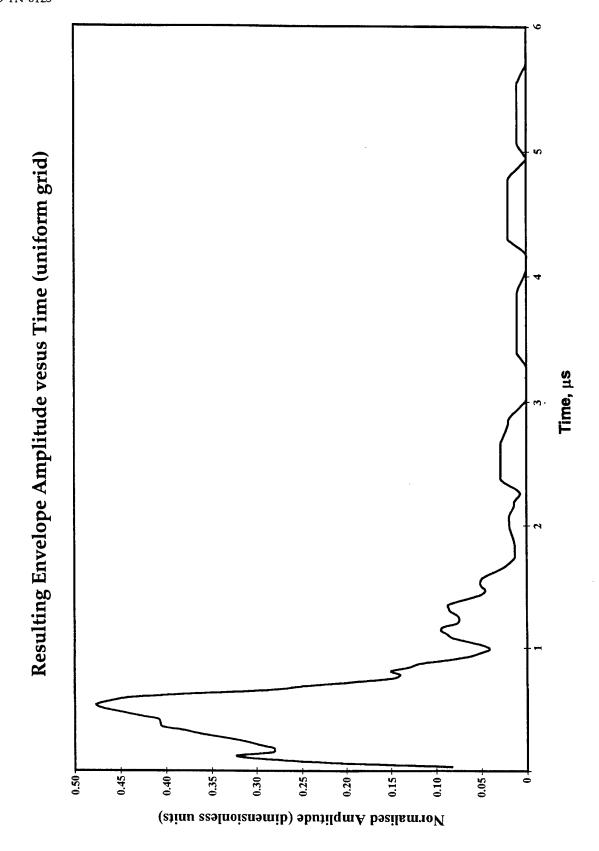
Beamwidth angle beta (degrees): 1.2 Great circle distance I (km): 300 Elevation angle phi (degrees): 0.7 Number of knots inside the scattering volume n: 1000 Operating frequency (MHz): 2830 Pulse rise time (μ s): 0.1 Pulse width (μ s): 0.5 Pulse fall time (μ s): 0.15

1	Time(i)	Am	plitude	i	Time[i]	Arr	plitude	i	Time[i]	An	nplitude	i	Time[i]	Arr	plitude	, ,	Time[i]	Αп	plitude
		(arbit	rary units)			(arbit	rary units)			(arbit	rary units)			(arbit	rary units)	1		(arbit	rary units)
		Initial	Resulting			Initial	Resulting			Initial	Resulting			Initial	Resulting			Initial	Resulting
1	0.03	0.3	0.733	43	1.29	0	0	85	2.55	0	0	127	3.81	0	0	169	5.07	0	0
2	0.06	0.6	1.645	44	1.32	0	0	86	2.58	0	0	128	3.84	0	0	170	5.1	0	0
3	0.09	0.9	7.693	45	1.35	0	0	87	2.61	0	0	129	3.87	0	0	171	5.13	0	0
4	0.12	1	17.318	46	1.38	0	0	88	2.64	0	0	130	3.9	0	0	172	5.16	0	0
5	0.15	1	24.379	47	1.41	0	0	89	2.67	0	0	131	3.93	0	0	173	5.19	0	0
6	0.18	1	27.143	48	1.44	0	0	90	2.7	0	0	132	3.96	0	0	174	5.22	0	0
7	0.21	1	25.031	49	1.47	0	0	91	2.73	0	0	133	3.99	0	0	175	5.25	0	0
8	0.24	1	23.353	50	1.5	0	0	92	2.76	0	0	134	4.02	0	0	176	5.28	0	0
9	0.27	1	22.825	51	1.53	٥	0	93	2.79	٥	٥	135	4.05	0	0	177	5.31	٥	0
10	0.3	1	22.686	52	1.58	0	0	94	2.82	٥	0	136	4.08	0	0	178	5.34	0	0
11	0.33	1	22.686	53	1.59	٥	0	95	2.85	0	0	137	4.11	0	0	179	5.37	0	0
12	0.36	1	22.686	54	1.62	0	0	96	2.88	0	0	138	4.14	0	0	180	5.4	0	0
13	0.39	1	22.686	55	1.65	0	0	97	2.91	0	0	139	4.17	٥	0	181	5.43	0	0
14	0.42	1	22.686	58	1.68	٥	٥	98	2.94	0	٥	140	4.2	0	0	182	5.46	٥	0
15	0.45	1	22.686	57	1.71	٥	0	99	2.97	٥	0	141	4.23	0	0	183	5.49	٥	0
16	0.48	1	22.686	58	1.74	٥	0	100	3	0	0	142	4.26	0	0	184	5.52	0	0
17	0.51	1	22.686	59	1	٥	0	101	3.03	0	0	143	4.29	0	٥	185	5.55	0	0
18	1	1	22.686	60		0	0	102	3.06	0	٥	144	4.32	٥	٥	186	5.58	0	0
19		1	22.686	61	1.83	0	٥	103	3.09	٥	٥	145	4.35	0	0	187	5.61	0	0
20	1	1	22.686	82		0	0	104	1	0	0	146	4.38	0	0	188	5.64	0	0
21		0.8	22.525	63	1	0	0	105		0	٥	147	4.41	0	٥	189	5.67	0	0
22		0.6	21,595	64	1	٥	0	106	1	٥	0	148	4.44	0	0	190	5.7	0	0
23	1	0.4	17.787	65		0	0	107	3.21	٥ ا	0	149	4.47	0	0	191	5.73	٥	0
24		0.2	12.583	66		٥	0	108		1 °	0	150	4.5	0	0	192	5.76	0	0
25	1	0	8.163	67		0	٥	109	1	0	٥	151	4.53	0	٥	193	5.79	0	0
26		0	4,978	68	i	0	0	110		0	0	152	4.56	0	0	194	5.82	0	٥
27		0	5.264	69		0	0	111		0	0	153		0	0	195	5.85	0	٥
20	1	0	4.45	70		0	0	112	1	0	0	154	1	0	0	198	5.88	0	0
29		0	1.643	71		0	0	113		0	0	155	1	0	0	197	5.91	0	0
34		0	0.232	72		0	0	114		0	0	156		0	0	198		0	0
3	1	0		73	_	0	0	116		0	0	157	1	ů	1	199	1	0	0
3:		i i	0	75	1 -	l °	"	117	1	"	Ü	159		0	0	1 200	6	Ι "	0
3	1	0		76	i i	"	"	111	1	"	"	160		l °	0		l		
3		1 %	"	77		"	"	1118		"	"	161		"	l ů	1		1	
3	1	"	"	78		"		120		"	"	162		0	, ,		1	1	l.
3		"	"	79		"	l ö	12		1 %	Ü	163	1	"	l o	1	1		
٦	1	"	l ů	80	1	"	"	12	1	l ö	l °	164		۱ ،	"	I		1	
١	1	1 "	"	8		1 "	"	123		"	"	165		l ő	"	1	1	1	1
14		"	"	8:		1 %	"	12		"	l ő	160		"	"	1		1	
1		"	"	8		"	"	12	1	l ő	0	16	1	1 0	l °	1	1	1	
4		1 0	l ö	8		1 0	"	12		1 0	"	16		"	"			1	1



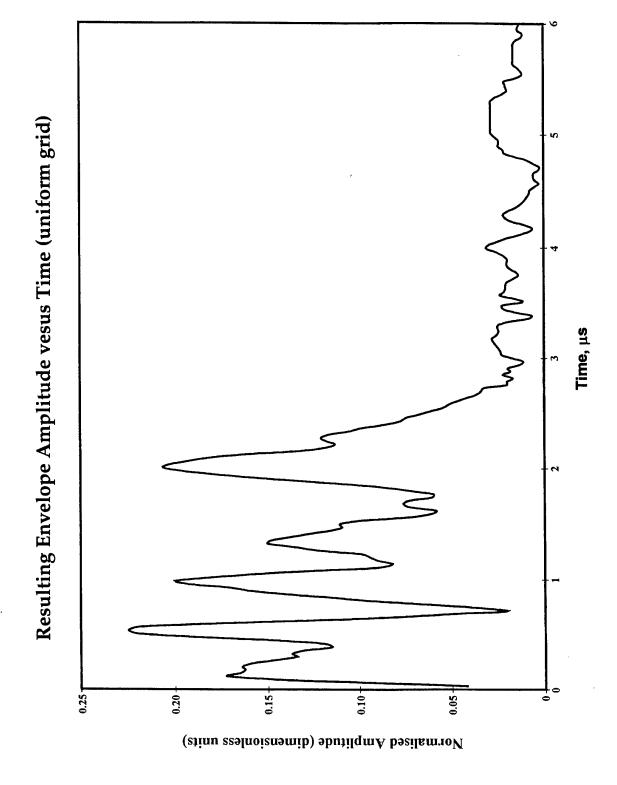
Beamwidth angle beta (degrees): 2 Great circle distance I (km): 300 Elevation angle phi (degrees): 5 Number of knots inside the scattering volume n: 1000 Operating frequency (MHz): 2800 Pulse rise time (μ s): 0.1 Pulse width (μ s): 0.5 Pulse fall time (μ s): 0.15

		Time[i]	Am	plitude	i l	Time[i]	Am	plitude	i	Time[i]	Arr	plitude	i	Time[i]	Am	plitude	i	Time[i]	Am	plitude
		7						·		.,	(arbit	rary units)			(arbit	rary units)			(arbit	rary units)
1 0.03 0.3 1.092 43 1.29 0 10.602 85 2.55 0 0 0 127 3.81 0 0 0 168 507 2 0 0 0 6 0.6 2.227 44 1.32 0 10.161 86 2.58 0 0 0 129 3.87 0 0 177 5.1 1 3 0.09 0.9 2.725 45 1.35 0 9.798 87 2.61 0 0 0 129 3.87 0 0 177 5.1 1 4 0.12 1 3.266 46 1.38 0 7.356 88 2.64 0 0 130 3.9 0 0 172 5.16 5 0.15 1 5.524 47 1.41 0 5.425 89 2.67 0 0 0 130 3.9 0 0 177 5.1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1			<u> </u>								<u> </u>			Į l	Initial	Resulting			Initial	Resulting
2 006 0.6 2.27 44 1.32 0 10.161 86 2.58 0 0 0 128 3.84 0 0 0 170 5.1 3 0.00 0.9 2.725 45 1.35 0 9.788 87 2.61 0 0 129 3.87 0 0 0 171 5.36 1	H	0.03			43	1 29	_		85	2.55			127	3.81	0	0	169	5.07	0	0
3					1 1		. 1	· i						3.84	0	0	170	5.1	0	0
4 0.12 1 3.286 46 1.38 0 7.386 88 2.84 0 0 0 130 3.9 0 0 172 5.16 5 0.15 1 5.524 47 1.41 0 5.425 89 2.67 0 0 131 3.93 0 0 1774 5.12 6 0.21 1 13.159 49 1.47 0 5.154 91 2.73 0 0 133 3.99 0 0 176 5.25 8 0.24 1 16.307 50 1.5 0 4.411 92 2.76 0 0 134 402 0 1776 5.25 9 0.27 1 16.142 51 1.53 0 4.54 95 2.85 0 0 135 4.05 0 1778 5.31 11 0.33 1 2.3898 53 1.55			1 1		i !		l 1		87		0	0	129	3.87	0	0	171	5,13	0	0
5						l	i I		88	2.64	0	0	130	3.9	0	0	172	5.16	0	0
7 0.21 1 131.59 49 1.47 0 5154 91 2.73 0 0 133 3.99 0 0 0 175 5.25 8 0.24 1 16.307 50 1.5 0 4.411 92 2.76 0 0 0 134 4.02 0 0 0 176 5.28 9 0.27 1 16.142 51 1.53 0 4.23 93 2.79 0 0 0 135 4.05 0 0 0 177 5.31 10 0.3 1 20.073 52 1.56 0 4.565 94 2.82 0 0 136 4.088 0 0 0 178 5.37 11 0.33 1 20.898 53 1.59 0 4.54 95 2.85 0 0 0 136 4.08 0 0 0 178 5.34 11 0.33 1 20.898 53 1.59 0 4.54 95 2.85 0 0 0 136 4.088 0 0 0 178 5.37 11 0.36 1 30.99 1 36.069 55 1.65 0 3.43 97 2.91 0 0 139 4.17 0 0 180 5.4 13 0.39 1 36.069 55 1.65 0 3.43 97 2.91 0 0 139 4.17 0 0 181 5.43 11 0.39 1 38.089 55 1.55 1.65 0 3.43 97 2.91 0 0 140 4.2 0 0 180 5.4 11 0.34 11 0.3 1 39.632 58 1.74 0 0.511 100 3 0 0 141 4.2 0 0 0 182 5.45 11 0.45 11 39.632 58 1.74 0 0.511 100 3 0 0 142 4.26 0 0 182 5.45 11 0.51 1 35.67 80 1.8 0 0.111 100 3 0 0 142 4.26 0 0 183 5.49 11 0.55 1 3.55 11 35.67 80 1.8 0 0 0 113 100 3.00 0 144 4.32 0 0 185 5.55 11 0.55 1 3.55 7 0.0 1.8 0 0.0 110 3.03 0 0 144 4.32 0 0 186 5.55 11 0.55 1 3.55 7 0.0 1.8 0 0.0 110 3.03 0 0 144 3.42 0 0 0 186 5.55 11 0.55 1 3.55 7 0.0 1.8 0 0.0 110 3.03 0 0 144 3.42 0 0 0 186 5.55 11 0.55 1 3.55 7 0.0 1.8 0 0.0 110 3.03 0 0 144 3.42 0 0 0 186 5.55 11 0.55 1 3.55 7 0.0 1.8 0 0.0 110 3.03 0 0 144 3.42 0 0 0 186 5.55 11 0.55 1 3.57 80 1 3.57 80 1 3.8 0 0 0 105 3.15 0 0 144 4.47 0 0 186 5.55 12 0.50 1 1.5		1		i I		1.41	0	5.425	89	2.67	0	0	131	3.93	0	0	173	5.19	0	0
8 0.24 1 16.307 50 1.5 0 4.411 92 2.76 0 0 134 402 0 0 176 5.28 9 0.27 1 16.142 51 1.53 0 4.232 93 2.79 0 0 0 135 4.05 0 0 0 177 5.31 10 0.3 1 20.073 52 1.56 0 4.565 94 2.82 0 0 136 4.08 0 0 177 5.31 12 0.38 53 1.59 0 4.54 95 2.85 0 0 137 4.11 0 0 0 178 5.34 11 0.33 1 38.089 53 1.59 0 4.54 95 2.85 0 0 137 4.11 0 0 0 180 5.4 13 0.39 1 38.089 55 1.65 0 4.576 96 2.88 0 0 137 4.11 0 0 0 180 5.4 13 0.39 1 38.089 55 1.65 0 2.202 98 2.94 0 0 140 4.2 0 0 181 5.43 14 0.42 1 39.101 56 1.68 0 2.202 98 2.94 0 0 140 4.2 0 0 182 5.46 16 0.48 1 39.632 58 1.74 0 0.511 100 3 0 0 141 4.23 0 0 0 183 5.49 16 0.48 1 39.632 58 1.74 0 0.511 100 3 0 0 142 4.26 0 0 188 5.52 17 0.51 1 37.914 59 1.77 0 0.311 101 3.03 0 0 144 4.32 0 0 185 5.55 18 0.54 1 35.567 60 1.8 0 0 0.111 102 3.08 0 0 144 4.32 0 0 186 5.55 18 0.54 1 35.575 62 1.86 0 0 0 103 3.09 0 0 144 4.32 0 0 186 5.55 18 0.57 1 34.7 61 1.83 0 0 0 103 3.09 0 0 144 4.35 0 0 187 5.81 20 0 6.8 17 5.81 20 0.8 1 35.275 62 1.86 0 0 0 105 3.15 0 0 146 4.38 0 0 0 187 5.81 20 0 0 188 5.64 21 0.63 0 8 37.683 83 1.89 0 0 0 105 3.15 0 0 144 4.38 0 0 0 187 5.61 20 0.68 0 4 43.956 65 1.95 0 0 0 105 3.15 0 0 144 4.41 0 0 0 189 5.67 22 0.66 0.6 41.095 64 1.92 0 0 106 3.18 0 0 144 4.40 0 0 190 5.7 24 0.72 0.2 44.555 66 1.98 0 0 0 105 3.15 0 0 144 4.40 0 0 190 5.7 24 0.72 0.2 44.555 66 1.98 0 0 0 105 3.15 0 0 155 4.50 0 0 191 5.73 24 0.72 0.2 44.555 66 1.98 0 0 0 105 3.15 0 0 0 155 4.50 0 0 192 5.75 22 0.69 0.4 43.956 65 1.95 0 0 0 106 3.18 0 0 155 4.50 0 0 193 5.79 24 0.72 0.2 44.555 66 1.98 0 0 0 105 3.15 0 0 0 155 4.50 0 0 192 5.75 22 0.60 0.6 41.212 68 2.04 0 0 110 3.3 0 0 0 155 4.62 0 0 0 195 5.85 28 0.84 0 36.87 7 2.01 0 0 110 3.3 0 0 0 155 4.62 0 0 0 195 5.85 28 0.84 0 36.87 7 2.21 0 0 0 110 3.3 0 0 0 155 4.80 0 0 0 196 5.85 28 0.84 0 36.87 7 2.21 0 0 0 110 3.3 0 0 0 155 4.80 0 0 0 196 5.85 28 0.84 0 0 0 1.85 5.85 7 0 0 0 110 3.3 0 0 0 155 4.80 0 0 0 196 5.85 28 0.85 0 0 0 196 5.85 28 0.85 0 0 0 0 186 5.80 0 0 0 196 5.85 0 0 0 0 196 5.85 0 0 0 0 196 5.85 0 0 0 0 196 5.85 0 0 0 0 196 5.85 0 0	6	0.18	1	9.197	48	1.44	0	4.941	90	2.7	0	0	132	3.96	0	0	174	5.22	0	0
9 0.27 1 1 16.42 51 1.53 0 4.23 93 2.79 0 0 135 4.05 0 0 177 5.31 10 0.3 1 20.073 52 1.56 0 4.565 94 2.82 0 0 0 136 4.08 0 0 0 178 5.34 11 0.33 1 23.898 53 1.59 0 4.576 96 2.88 0 0 0 137 4.11 0 0 179 5.37 12 0.36 1 30.251 54 1.82 0 4.576 96 2.88 0 0 0 138 4.14 0 0 180 5.4 13 0.39 1 36.069 55 1.65 0 3.43 97 2.91 0 0 139 4.17 0 0 181 5.43 14 0.42 1 39.101 56 1.88 0 2.202 98 2.94 0 0 140 4.2 0 0 182 5.46 15 0.45 1 41.745 57 1.71 0 0.875 99 2.97 0 0 141 4.23 0 0 183 5.49 18 0.45 1 38.632 58 1.74 0 0.511 100 3 0 0 143 4.29 0 0 183 5.55 18 0.54 1 35.567 80 1.8 0 0.111 102 3.08 0 0 144 4.22 0 0 188 5.55 18 0.57 1 33.794 99 1.77 0 0.311 101 3.03 0 0 143 4.29 0 0 185 5.55 18 0.57 1 33.763 83 1.89 0 0.111 102 3.08 0 0 144 4.32 0 0 188 5.58 19 0.57 1 33.7683 83 1.89 0 0 104 3.12 0 0 145 4.35 0 0 188 5.58 19 0.57 1 33.7683 83 1.89 0 0 104 3.12 0 0 145 4.35 0 0 188 5.61 20 0.66 1 35.275 62 1.86 0 0 104 3.12 0 0 145 4.35 0 0 188 5.61 20 0.66 1 35.275 62 1.86 0 0 104 3.12 0 0 145 4.35 0 0 188 5.61 20 0.66 1 35.275 62 1.86 0 0 105 3.15 0 0 147 4.41 0 0 189 5.67 22 0.66 0.6 41.095 84 1.92 0 0 106 3.18 0 0 147 4.41 0 0 189 5.67 22 0.66 0.6 41.095 84 1.92 0 0 0 105 3.15 0 0 147 4.41 0 0 189 5.67 22 0.66 0.6 41.095 84 1.92 0 0 0 106 3.18 0 0 147 4.41 0 0 0 189 5.67 22 0.66 0.6 41.095 84 1.92 0 0 0 106 3.18 0 0 147 4.41 0 0 0 189 5.67 22 0.66 0.6 41.095 84 1.92 0 0 0 106 3.18 0 0 147 4.41 0 0 0 189 5.67 22 0.66 0.6 41.095 84 1.92 0 0 0 106 3.18 0 0 147 4.41 0 0 0 189 5.67 22 0.60 0.6 41.095 84 1.92 0 0 0 106 3.24 0 0 155 4.56 0 0 193 5.79 28 0.75 0 43.177 67 2.01 0 0 110 3.3 0 0 0 155 4.56 0 0 193 5.79 28 0.75 0 43.177 67 2.01 0 0 110 3.3 0 0 0 155 4.56 0 0 193 5.79 28 0.75 0 43.177 67 2.01 0 0 110 3.3 0 0 0 155 4.56 0 0 0 194 5.52 4.56 0 0 0 195 5.85 28 0.84 0 38.653 69 2.07 0 0 0 113 3.39 0 0 0 156 4.86 0 0 0 195 5.85 28 0.84 0 38.653 69 2.07 0 0 0 113 3.39 0 0 0 156 4.86 0 0 0 196 5.85 28 0.84 0 38.653 69 2.07 0 0 0 113 3.39 0 0 0 156 4.86 0 0 0 196 5.85 28 0 0 0 0 156 5.85 28 0 0 0 0 156 5.85 28 0 0 0 0 156 5.85 29 0 0 0 156 5.	7	0.21	1	13.159	49	1.47	0	5.154	91	2.73	0	0	133	3.99	0	0	175	5.25	0	0
10	8	0.24	1	16.307	50	1.5	0	4.411	92	2.76	0	0	134	4.02	0	0	176	5.28	0	0
11	9	0.27	1	16.142	51	1.53	0	4.223	93	2.79	0	0	135	4.05	٥	0	177	5.31	0	0
12 0.36 1 30.251 54 1.62 0 4.576 96 2.88 0 0 0 138 4.14 0 0 180 5.4 13 0.39 1 36.069 55 1.65 0 3.43 97 2.91 0 0 139 4.17 0 0 181 5.43 14 0.42 1 39.101 56 1.68 0 2.202 98 2.94 0 0 0 140 4.2 0 0 182 5.46 15 0.45 1 41.745 57 1.71 0 0.875 99 2.97 0 0 141 4.2 3 0 0 183 5.49 18 0.48 1 39.632 58 1.74 0 0.511 100 3 0 0 144 4.2 0 0 0 183 5.49 18 0.54 1 37.914 59 1.77 0 0.311 101 3.03 0 0 143 4.29 0 0 185 5.55 18 0.54 1 35.567 60 1.8 0 0.111 102 3.08 0 0 144 4.32 0 0 186 5.58 19 0.57 1 34.7 61 1.83 0 0 103 3.09 0 0 144 4.32 0 0 186 5.58 19 0.57 1 35.575 62 1.86 0 0 103 3.09 0 0 144 4.32 0 0 188 5.67 20 0.6 1 35.275 62 1.86 0 0 104 3.12 0 0 146 4.35 0 0 188 5.67 22 0.66 0.6 41.095 64 1.92 0 0 106 3.15 0 0 148 4.44 0 0 189 5.67 22 0.66 0.6 41.095 64 1.92 0 0 106 3.15 0 0 148 4.44 0 0 199 5.7 23 0.89 0.4 43.956 65 1.95 0 0 108 3.24 0 0 150 4.5 0 0 192 5.76 25 0.75 0 43.177 67 2.01 0 0 109 3.27 0 0 151 4.53 0 0 192 5.76 25 0.75 0 43.177 67 2.01 0 0 109 3.27 0 0 151 4.53 0 0 192 5.76 26 0.78 0 41.212 68 2.04 0 0 110 3.33 0 0 152 4.56 0 0 193 5.82 27 0.81 0 38.653 69 2.07 0 0 111 3.33 0 0 155 4.65 0 0 193 5.82 29 0.87 0 33.739 71 2.13 0 0 110 3.39 0 0 155 4.65 0 0 199 5.82 29 0.87 0 33.739 71 2.13 0 0 110 3.39 0 0 155 4.65 0 0 199 5.82 29 0.87 0 33.739 71 2.13 0 0 111 3.33 0 0 155 4.65 0 0 199 5.82 29 0.87 0 33.739 71 2.13 0 0 110 3.34 0 0 155 4.65 0 0 199 5.83 29 0.87 0 33.739 71 2.13 0 0 111 3.33 0 0 155 4.65 0 0 199 5.83 29 0.87 0 33.739 71 2.13 0 0 111 3.34 0 0 155 4.65 0 0 199 5.83 29 0.87 0 33.739 71 2.13 0 0 111 3.34 0 0 155 4.65 0 0 0 196 5.83 29 0.87 0 32.708 75 2.216 0 0 111 3.35 0 0 155 4.65 0 0 0 196 5.83 29 0.87 0 32.708 75 2.216 0 0 111 3.35 0 0 155 4.65 0 0 0 196 5.83 29 0.87 0 32.708 75 2.216 0 0 111 3.35 0 0 155 4.65 0 0 0 196 5.83 29 0.87 0 32.708 75 2.216 0 0 111 3.35 0 0 0 155 4.65 0 0 0 196 5.83 29 0.87 0 32.708 75 2.216 0 0 111 3.35 0 0 0 155 4.65 0 0 0 196 5.83 29 0.87 0 33.739 71 2.13 0 0 0 113 3.45 0 0 0 166 4.8 0 0 0 196 5.83 20 0.98 0 6 0.22756 74 2.22 0 0 0 118 3.46 0 0 0 166 4.8 0 0 0 196 5.94 20 0	10	0.3	1	20.073	52	1.56	0	4.565	94	2.82	0	0	136	4.08	0	1	1		0	0
13 0.39 1 38.069 55 1.85 0 3.43 97 2.91 0 0 139 4.17 0 0 181 5.43 14 0.42 1 39.101 56 1.68 0 2.202 98 2.94 0 0 140 4.2 0 0 182 5.46 15 0.45 1 41.745 57 1.71 0 0.875 99 2.97 0 0 141 4.23 0 0 0 183 5.49 16 0.48 1 39.632 58 1.74 0 0.511 100 3 0 0 142 4.26 0 0 183 5.49 17 0.51 1 37.914 59 1.77 0 0.311 101 30.33 0 0 142 4.26 0 0 185 5.55 18 0.54 1 35.567 60 1.8 0 0.111 102 3.06 0 0 144 4.32 0 0 0 185 5.55 19 0.57 1 34.7 61 1.83 0 0 0 103 3.09 0 0 144 4.32 0 0 0 186 5.56 19 0.57 1 34.7 61 1.83 0 0 0 104 3.12 0 0 146 4.38 0 0 186 5.56 19 0.57 1 34.7 61 1.83 0 0 0 103 3.09 0 0 144 4.32 0 0 0 186 5.56 19 0.66 1 35.275 62 1.86 0 0 105 3.15 0 0 146 4.38 0 0 0 187 5.61 20 0.66 0 0 144 4.39 0 0 0 187 5.61 20 0.66 0 0 0 144 4.39 0 0 0 187 5.61 20 0.66 0 0 0 144 4.39 0 0 0 187 5.61 20 0.66 0 0 0 144 4.39 0 0 0 187 5.61 20 0.67 14 1 34.956 0 0 0 105 3.15 0 0 0 147 4.41 0 0 0 189 5.67 22 0.66 0.66 41.095 64 1.92 0 0 106 3.18 0 0 148 4.44 0 0 190 5.7 23 0.69 0 4.4 43.956 65 1.95 0 0 108 3.24 0 0 148 4.47 0 0 191 5.73 24 0.72 0.2 44.555 66 1.98 0 0 108 3.24 0 0 148 4.47 0 0 191 5.73 24 0.72 0.2 44.555 66 1.98 0 0 108 3.27 0 0 155 4.5 0 0 192 5.76 25 0.75 0 43.177 67 2.01 0 0 109 3.27 0 0 155 4.5 0 0 192 5.76 25 0.75 0 43.177 67 2.01 0 0 109 3.27 0 0 155 4.5 0 0 192 5.76 28 0.84 0 36.077 70 2.1 0 0 111 3.33 0 0 152 4.56 0 0 199 5.79 26 0.78 0 41.212 68 2.04 0 0 113 3.39 0 0 155 4.65 0 0 199 5.88 29 0.87 0 33.739 71 2.13 0 0 111 3.33 0 0 155 4.65 0 0 199 5.88 29 0.87 0 33.739 71 2.13 0 0 113 3.39 0 0 155 4.65 0 0 199 5.88 29 0.87 0 33.739 71 2.13 0 0 111 3.35 0 0 155 4.65 0 0 199 5.88 29 0.87 0 33.739 71 2.13 0 0 111 3.35 0 0 155 4.65 0 0 0 199 5.88 23 0.89 0 16.288 75 2.25 0 0 111 3.35 0 0 156 4.88 0 0 0 199 5.97 30 0.99 0 16.288 75 2.25 0 0 111 3.35 0 0 156 4.88 0 0 0 199 5.97 31 0.99 0 16.288 75 2.25 0 0 111 3.35 0 0 0 160 4.8 0 0 0 199 5.97 31 0.99 0 16.288 75 2.25 0 0 111 3.35 0 0 0 160 4.8 0 0 0 199 5.97 31 10 0 112 3.63 0 0 160 4.8 0 0 0 199 5.97 31 10 0 112 3.60 0 0 166 4.8 0 0 0 199 5.97 31 10 0 112 3.60 0 0 166 4.8 0 0 0	11	0.33	1	23.898	53	1.59	0				_		ĮI .	1	1	l	II .	1	0	0
14 0.42 1 39 101 56 1.88 0 2.202 98 2.94 0 0 140 4.2 0 0 182 5.46 15 0.45 1 41.745 57 1.71 0 0.875 99 2.97 0 0 141 4.23 0 0 183 5.49 16 0.48 1 39.632 58 1.74 0 0.511 100 3 0 0 142 4.26 0 0 184 5.52 18 0.54 1 35.567 60 1.8 0 0.111 102 3.08 0 0 144 4.32 0 0 185 5.55 18 0.57 1 34.7 61 1.83 0 0 103 3.09 0 0 144 4.32 0 0 188 5.68 20 0.6 6 41.92	12	0.36	1		11				!!	1	1	i	II .			ľ	Ħ		0	0
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18			1		II .	1			H	1	1	1	n		1	1	11		0	0
17	1		ŀ		II .				B	1	1	1	il		1		n		l °	0
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31 0.93 0 27.016 73 2.19 0 0 115 3.45 0 0 157 4.71 0 0 199 5.97 32 0.96 0 22.756 74 2.22 0 0 116 3.48 0 0 158 4.74 0 0 200 6 33 0.99 0 16.268 75 2.25 0 0 117 3.51 0 0 159 4.77 0 0 34 1.02 0 10.254 76 2.28 0 0 118 3.54 0 0 160 4.8 0 0 35 1.05 0 6.895 77 2.31 0 0 119 3.57 0 0 160 4.8 0 0 36 1.08 0 6.736 78 2.34 0 0 120 3.6 0 0 162 4.88 0 0 37 1.11 0 7.38 79 2.37 0 0 120 3.6 0 0 162 4.88 0 0 37 1.11 0 7.38 79 2.37 0 0 121 3.63 0 0 162 4.89 0 0 38 1.14 0 7.985 80 2.4 0 0 122 3.66 0 0 164 4.92 0 0 38 1.17 0 8.08 81 2.43 0 0 122 3.66 0 0 165 4.95 0 0	2	0.87	0	33.739	7.	2.13	0	0	113	3.39	0	0	15	5 4.65	0	0	19	7 5.91	٥	0
32 0.98 0 22.756 74 2.22 0 0 116 3.48 0 0 158 4.74 0 0 200 6 33 0.99 0 16.268 75 2.25 0 0 117 3.51 0 0 158 4.77 0 0 34 1.02 0 10.254 76 2.28 0 0 118 3.54 0 0 160 4.8 0 0 35 1.05 0 6.895 77 2.31 0 0 119 3.57 0 0 161 4.83 0 0 36 1.08 0 6.736 78 2.34 0 0 120 3.6 0 0 162 4.86 0 0 37 1.11 0 7.38 79 2.37 0 0 121 3.63 0 0 163 4.89 0 0 38 1.14 0 7.985 80 2.4 0 0 122 3.66 0 0 164 4.92 0 0 39 1.17 0 8.08 81 2.43 0 0 122 3.66 0 0 165 4.95 0 0	3	0.9	0	30.5	7:	2 2.16	٥	0	114	4 3.42	0	٥	15	8 4.68	0	0	11	1	0	0
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38 1.14 0 7.985 80 2.4 0 0 122 3.66 0 0 164 4.92 0 0 39 1.17 0 8.08 81 2.43 0 0 123 3.69 0 0 165 4.95 0 0			i		13		1	1	11				- 11			1		1	1	
39 1.17 0 8.08 81 2.43 0 0 123 3.69 0 0 165 4.95 0 0		1		1	11	1 "	1 -	_	11		1	1	11	- 1			-	1	1	
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[40] 1.2 [U] 6.000 [62] 2.46 [U] U [124] 3.72 [U] U [100] 4.96] U] U [1	1 -		-11	1	- 1	1	- 11	1			II.		- 1	1			1	
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Beamwidth angle beta (degrees): 4 Great circle distance I (km): 300 Elevation angle phi (degrees): 2.1 Number of knots inside the scattering volume n: 1000 Operating frequency (MHz): 2830 Pulse rise time (μ s): 0.1 Pulse width (μ s): 0.5 Pulse fall time (μ s): 0.15

	Ti		A	litude	. 1	Time[i]	Am	plitude		Time(i)	Am	plitude	l i	Time(i)	A	nplitude	i	Time[i]	Am	plitude
'	Time[i	~ I		1	.	Illinolii		ary units)				rary units)			(arbi	trary units)			(arbit	ary units)
1		_	_	ry units)	li		Initial	Resulting			Initial	Resulting			Initial	Resulting			Initial	Resulting
H	-	_		Resulting	4	1.29	0	8.341	85	2.55	0	2.813	127	3.81	0	1	169	5.07	0	1
1	0.03		1.3	8.325 20.664	43	1.29	0	8.607	86	2.58	٥	2.813	128	3.84	1	1 1	170	5.1	0	1
2	0.0		0.9	28.265	45	1.35	0	8.636	87	2.61	0	2.813	129	3.87	٠ ا	1 1	171	5.13	0	1
3 4	0.0		1	32.298	46	1.38	١٠	7.286	88	2.64	0	2.813	130	3.9	0	0.924	172	5.16	0	1
5	0.1	- 1	;	28.21	47	1.41	0	5.836	89	2.67	0	2.785	131	3.93	0	0.724	173	5.19	٥	1
6	0.1		;	28.058	48	1.44	ا	4.864	90	2.7	0	2.613	132	3.96	. 0	0.524	174	5.22	0	1
7	0.2		i	29.739	49	1.47	٥	4.535	91	2.73	0	2.444	133	3.99	0	0.324	175	5.25	٥	1
8	0.2		1	31,349	50	1.5	0	5.002	92	2.76	٥	2.282	134	4.02	2 0	0.124	176	5.28	0	1 1
9	0.2		1	33.626	51	1.53	0	5.114	93	2.79	٥	2.125	135	4.05	5 0	0	177	5.31	٥	1
10	0.	3	1	36.175	52	1.56	0	4.929	94	2.82	0	2	136	4.08	3 0	٥	178	5.34	l °	1 1
11	0.3	33	1	38.007	53	1.59	0	4.348	95	2.85	٥	2	13	7 4.1	1 0	0	179	5.37	٥	1
12	0.3	36	1	40.448	54	1.62	0	3.415	96	2.88	0	1.749	13		- 1	٥	180	5.4	0	1 1
13	0.3	39	1	40.695	55	1.65	٥	2.604	97	2.91	0	1.349	13		- 1	0	181	5.43	0	1
14	0.4	42	1	40.907	56	1.68	0	2.063	98	2.94	٥	0.949	14	1		0,319	182	1	0	1 1
15	0.4	45	1	43.106	57	1.71	0	1.641	99	2.97	0	0.549	14	1	ı	0.919	183		0	1 !
16	0.4	48	1	44.858	58	1.74	٥	1.285	100	1	0	0.149	14			1.519	184	1	0	1 1
17	0,	51	1	46.885	59	1.77	0	1.285	101		١ ۰	0	14		- 1	2	189	1	"	0.816
18	O.:	54	1	47.681	60		0	1.285	103		0	0	111		ı	2 2	183	1	1 0	0.616
11) O.	.57	1	46.215	61		٥	1.285	100		1 0	0	14	- 1	1	2	18	i i	1 %	0.418
2		3.6	1	43.815	62	1	٥	1.361	10		0	0	14	- 1	-	2	18	L	١	0.216
2	ı	.63	0.8	37.396	63	1	٥	1.47	10	1	0	0	14	1		2	19	1	0	0.016
2	1	.66	0.6	28.39	6	1	0	1.597	10	1	1 %	"	1 1	- 1		2	19		1	0
2		.69	0.4	24,574	6:	1	0	1.731	10			"	1	1	1		19	1	1	0
2		.72	0.2	19.463	6		1	1.864	10	ı	0	"	11		1	l l	19	-	1	0
2		.75	0	14.717	6	l l	0	1.893	11		1 0	0.114	- 11	52 4.			19		1	٥
2	1	1.78	0	13.98	6			1.922	11			0.114	- 11	53 4.	- 1	- 1	19	ı		0
12),81	0	14.974	н	9 2.07	"	1.73	111	1		0.714	Ш		62 0	2	19	6 5.88	0	0
		0.84	0	12.969 11.699	Ш	1 2.13		1,524	11			1	И	- 1	65 0	2	19	7 5.91	0	0
	i i	0.9	0	8.735	- 11	2 2.16		1.354	1			1	- 11		68 0	2	15	8 5.94	; o	0
- 1	- 1	0.93	0	6.322	ш	3 2.19		1.322				1	1	57 4.	71 (2	19	5.9	7 0	0
- 1		0.96	0	5.021	- 11	74 2.2	1	0.98	1	1		1	1	58 4	74 (2	20	00 6	٥	٥
		0.99	0	4.079	- 11	75 2.2	1 1	0.703	1	- 1	۰ ا ۱	1	1	59 4	.77	2	1	1	-	1
- 1		1.02	0	4.917	- 11	76 2.2		0.963	1	18 3.54	ه <u>ه</u>	1	- ∥ ₁	60 4	1.8	1.788				1
- 1	· I	1.05	0	6.483	п	77 2.3		1.66	1	19 3.5	7 0	1	- -	61 4	.83	1.388	1	1	1	1
		1.08	0	8.225	- 11	78 2.3	- 1	2.405	1	20 3.6	. 0	1 1	- 1	62 4	.86	0.988	·	- 1		1
1		1.11	0	8.815	- 11	79 2.3	- 1	2.813	ી∤	21 3.6	3 0	1	- -	163 4	.89	0.588	- 11		-	1
- 1	i	1.14	0	9.458		80 2.4	ه ۱	2.813	1	22 3.6	6 C	1	- -	164 4	.92	0.188	3 ∥	ı	- 1	1
- 1	- 1	1.17	0	9.176	.	81 2.4	3 0	2.813	1	23 3.6	9 0	1	- [165 4	.95	0 0	1		-	1
1	40	1.2	٥	7.649	,	82 2.4	6 0	2.813	1	24 3.7	2 (1	ı	166 4	1.98	0.27	- 14		- 1	
1	41	1.23	٥	7.412	2 ∦	83 2.4	9 0	2.813	- 11	25 3.7		1	- 11		5.01	0 0.57	- 11	1	- 1	1
1	42	1.26	٥	7.625	;	84 2.5	2 (2.813	3 1	26 3.7	8 (1		168	5.04	0 0.87	в		i_	

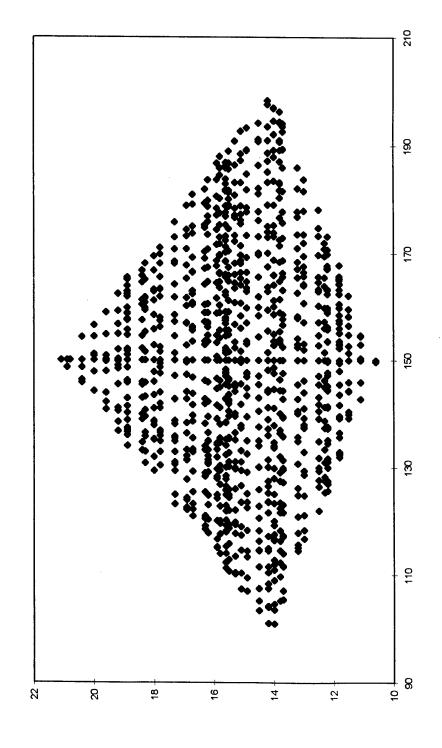


Beamwidth angle beta (degrees): 8
Great circle distance I (km): 300
Elevation angle phi (degrees): 4.1
Number of knots inside the scattering volume n: 1000
Operating frequency (MHz): 2830
Pulse rise time (μ s): 0.1
Pulse width (μ s): 0.5
Pulse fall time (μ s): 0.15

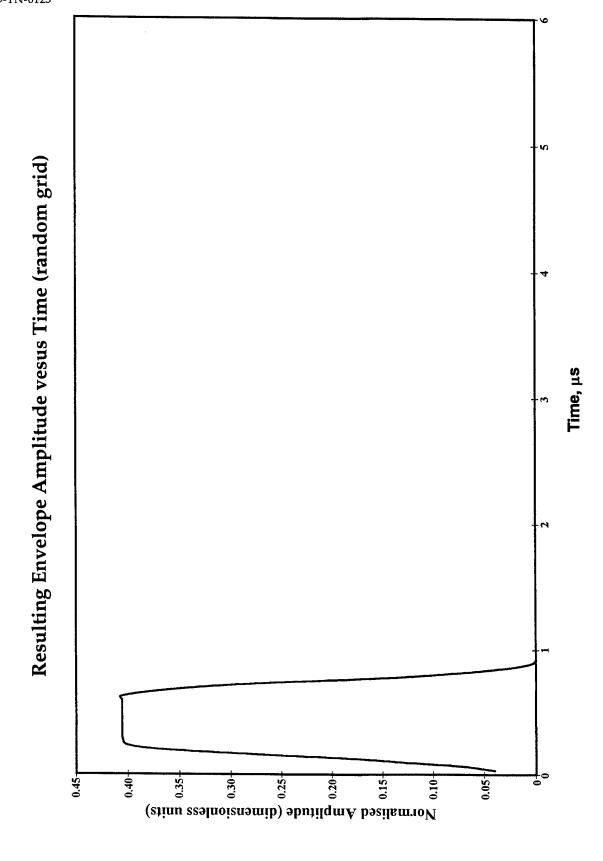
ī	Time[i]	Am	plitude	i	Time[i]	Am	plitude	i	Time[i]	Am	plitude	i.	Time[i]	Am	plitude	i	Time[i]	An	plitude
ı		(arbit	rary units)	l		(arbit	rary units)			(arbit	rary units)			(arbit	rary units)			(arbit	rary units)
l		Initial	Resulting			Initial	Resulting			Initial	Resulting			Initial	Resulting			Initial	Resulting
T	0.03	0.3	4.2	43	1.29	0	13.484	85	2.55	0	5.451	127	3.81	0	1.793	169	5.07	0	2.836
2	0.06	0.6	9.2	44	1.32	0	15	86	2.58	0	5.115	128	3.84	0	1.981	170	5.1	0	2.836
3	0.09	0.9	14.26	45	1.35	0	14.854	87	2.61	0	4.66	129	3.87	0	1.981	171	5.13	0	2.836
4	0,12	1	17.176	46	1.38	0	13.859	88	2.64	0	4.168	130	3.9	0	1.981	172	5.16	0	2,836
5	0.15	1	16.486	47	1.41	0	12.773	89	2.67	0	3.634	131	3.93	0	2.186	173	5.19	0	2.836
6	0.18	1	16.243	48	1.44	٥	11.524	90	2.7	0	3.373	132	3.96	٥	2.555	174	5.22	٥	2.836
7	0.21	1	16.386	49	1.47	0	10.928	91	2.73	0	3.22	133	3.99	0	3.061	175	5.25	0	2.836
8	0.24	1	15.854	50	1.5	٥	11.034	92	2.76	٥	2.017	134	4.02	0	2.968	176	5.28	0	2.836
9 10	0.27	1	14.569 13.437	51	1.53	0	9.837 7.151	93	2.79	0	1.989 1.685	135 136	4.05 4.08	0	2.538 2.041	177 178	5.31 5.34	"	2.836 2.635
11	0.33	1 1	13.437	52 53	1.59	0	6.056	95	2.82	0	2.208	137	4.11	i	1.336	179	5.34	l o	2.035
12	0.35	;	13.045	54	1.62	l 。	5.826	96	2.88	ů	1.81	138	4.14	ľ	0.77	180	5.4	"	1.98
13	0.39		11,505	55	1.65	0	7.212	97	2.91	0	1,938	139	4.17		0.612	181	5.43		2.017
14	0.42	1	11.937	56	1.68	0	7.585	98	2.94	0	1.316	140	4.2	0	1,077	182	5.46	0	2.064
15	0.45	1	14.357	57	1.71	0	7.246	99	2.97	0	1.122	141	4.23	0	1.803	183	5.49	0	2.1
16	0.48	1	18,554	58	1.74	0	6.036	100	3	0	1.761	142	4.26	٥	2.102	184	5.52	0	1.45
17	0.51	1	21.987	59	1.77	0	5.97	101	3.03	0	2.265	143	4.29	0	2.176	185	5.55	0	1.144
18	0.54	1	22.489	60	1.8	٥	7.327	102	3.06	0	2.339	144	4.32	0	1.903	186	5.58	0	1.233
19	0.57	1	21.963	81	1.83	0	8.785	103	3.09	0	2.446	145	4.35	٥	1.478	187	5.61	٥	1.424
20	0.6	1	18.668	62	1.86	0	10.634	104	3.12	٥	2,603	146	4.38	٥	1.22	188	5.64	0	1.638
21	0.63	0.8	13.431	63	L	٥	13.298	105	3.15	٥	2,713	147	4.41	0	1.039	189	5.67	٥	1.638
22		0.6	8.402	64	1	0	16.002	106	1	٥	2.791	148	4.44	0	0.902	190	1	0	1.638
23		0.4	5.118	65		0	18.004	107	3.21	0	2.539	149	4.47	0	0.788	191	5.73	0	1.638
24		0.2	2.062	66	i i	0	19.544	108	1	0	2.427	150	4.5	0	0.727	192		0	1.638 1.638
25	1	0	3.752 6.346	67 68	1	0	20.59	109		0	2.491	151 152	4.53 4.56	"	0.478	193 194	1	l "	1.638
27		l ő	9.377	69	_	"	19.236	111		l ö	1.987	153		"	0.491	195			1.494
28	i	l ö	11.257	70		0	18.03	112		"	0.858	154	1	"	0.55	196	1	"	1,185
29	1	"	13.937	71	1	•	16.221	113		0	0.643	155		0	0.537	197		•	1.139
30	1	•	15.914	72	1	•	13.427	114	1		1.614	156	1	0	0.28	198	1	0	1.379
31	0.93		17.166	73			11.844	115	3.45	0	2.226	157	4.71	٥	0.236	199	5.97	0	1.379
32	0.96	0	19.168	74	2.22	0	11.283	116	3.48	0	2.219	158	4.74		0.582	200	6	0	1.289
33	0.99	0	19.947	75	2.25	0	11.751	117	3.51	0	1.153	159	4.77	0	0.935	1	1	1	1
34	1.02	0	18.085	76	2.28	0	12.079	118	3.54	0	1.538	160	4.8	0	1.556	l	1	1	1
3.	1.05	0	15.624	77	7 2.31	٥	11.653	111	3.57	0	2.346	161	4.83	0	2.096	1		1	
36	1.08	٥	12.471	78	2.34	0	10.515	120	3.6	0	2.156	162	4.86	0	2.189		1		
3		٥	9.01	79		٥	9.894	12		0	2.068	163	1	٥	2.427				
34	1	0	8.165	80	1	٥	8.612	12:	1	0	2.07	164	1	0	2.426	1			1
3		۰ ا	8.997	8		0	7.762	12		0	1,996	16		0	2.436	1		1	1
14	1	0	9.42	8:	1	0	7.415	12		0	1.679	168		0	2.629	1		1	
1:		1 0	9.895	8	_	0	6.776 6.125	12 12		0	1.385	16	1	0	2.824 2.836		1		i
4	2 1.26	0	12.134	8	4 2.52	1 0	6.125	[12	0 3.78	1 0	1.481	116	5.04		2.030				1

DSTO-TN-0125

Appendix B: Computations of Radar Pulse Envelope Distortion for Random Distribution

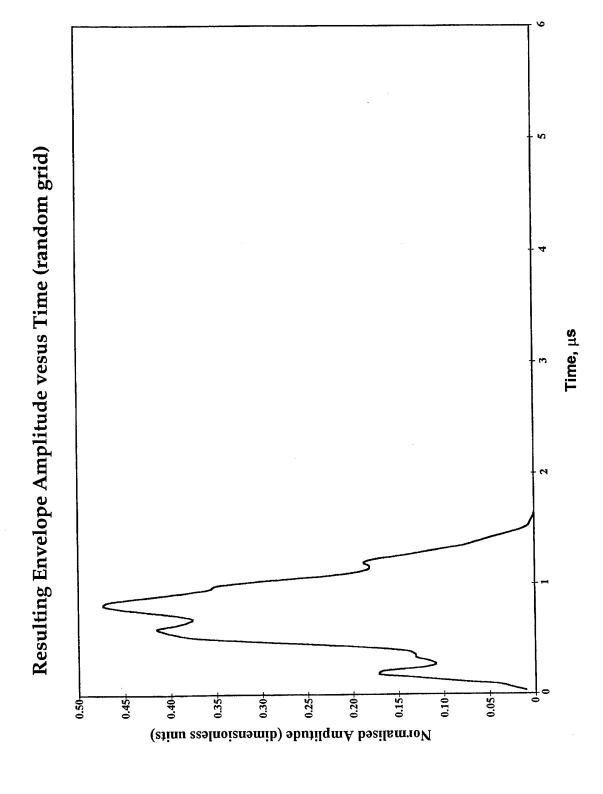


Grid with random distribtion of knots



Beamwidth angle beta (degrees): 1.2 Great circle distance I (km): 300 Elevation angle phi (degrees): 0.7 Number of knots inside the scattering volume n: 1000 Operating frequency (MHz): 2830 Pulse rise time (μ s): 0.1 Pulse width (μ s): 0.5 Pulse fall time (μ s): 0.15

Г	Time[i]	Α	plitude	i	Time[i]	۸۰۰۰	plitude	i	Time[i]	Δ-	plitude	i	Time[i]	Δ	plitude		Time[i]	An	plitude
Ι'	rune[i]		rary units)	'	rimeli		rary units)	'	imieli	ľ	rary units)		innefil	ľ	rary units)	'	111110[1]		rary units)
		Initial				Initial	Resulting		ľ	Initial	Resulting			Initial	Resulting			Initial	Resulting
H	0.03		Resulting 4.012	۳	4.00			85	2.55	unicai O	resulting 0	127	3.81	0	0	169	5.07	0	O C
1 2	0.03	0.3 0.8	7.129	43 44	1.29 1.32	0	0	86	2.55	0	٥	128	3.84	١	0	170	5.1	"	Ö
3	0.09	0.9	12.174	45	1.35	0	٥	87	2.61	ů	0	129	3.87		0	171	5,13	ů	0
4	0.12	1	17.2	46	1.38	0	ő	88	2.64	١٠	٥	130	3.9	اۃا	0	172	5.16	0	0
5	0.15		25.452	47	1.41	ا ا	o	89	2.67		٥	131	3.93	0	0	173	5.19	0	o
6	0.18	1	33.082	48	1.44		0	90	2.7	٥	٥	132	3.96	0	0	174	5.22	0	0
7	0.21	1	38.284	49	1.47	۰	0	91	2.73	0	0	133	3.99	0	0	175	5.25	0	0
8	0.24	1	40.247	50	1.5	0	0	92	2.76	0	0	134	4.02	0	0	176	5.28	0	0
9	0.27	1	40.471	51	1.53	٥	0	93	2.79	0	0	135	4.05	0	0	177	5,31	0	0
10	0,3	1	40.558	52	1,56	0	0	94	2.82	٥	0	136	4.08	0	٥	178	5.34	0	0
11	0.33	1	40.558	53	1.59	0	0	95	2.85	0	٥	137	4.11	0	٥	179	5.37	0	0
12	0.36	1	40.558	54	1.62	0	a	96	2.88	0	0	138	4.14	0	٥	180	5.4	0	0
13	0.39	1	40.558	55	1.65	0	0	97	2.91	0	٥	139	4.17	٥	0	181	5.43	٥	
14	0.42	1	40,558	56	1.68	٥	0	98	2.94	٥	٥	140	4.2	0	٥	182	5.46	0	0
15	0.45	1	40.558	57	1.71	٥	0	99	2.97	0	0	141	4.23	0	0	183	5.49	0	0
18	0.48	1	40.558	58	1.74	0	0	100	3	0	0	142	4.26	0	0	184	5.52	0	0
17	0.51	1 1	40.558	59	1.77	0	0	101	3.03	0	0	143	4.29	0	0	185 186	5.55 5.58	0	0
18	0.54	1 1	40.558	60	1.8	0	1 0	102 103	3.06	0	0	144 145	4.32	"	0	187	5.61	"	"
19	0.57	1	40.558	61	1.83	0	0	103	3,09	١	١	145	1	"	١	188	5.64	"	١،
20	0.63	0.8	40.558	62 63	1.86	0	l "	105	3.15	"		147	4.41	١٠	i	189	5.67	"	
22	0.66	0.6	38.705	64		l .	0	108	3.18	١٠	ا ن	148	4.44	0	Š	190	5.7	0	
23	1	0.4	35.273	65	1	١	0	107	3.21	0	1 0	149	1	0	0	191	5.73	0	0
24		0.2	30.394	68		٥	0	108	1	0	0	150	4.5	0		192	5.76	0	۰ ا
25	1	0	22,659	67	1	0	0	109	3.27	0		151	4.53	0	0	193	5,79	0	٥
26	0.78	0	14.311	68	2.04	0	0	110	3.3	0	0	152	4.56	0	0	194	5.82	0	٥
27	0.81	0	8.296	69	2.07	0	0	111	3.33	0	0	153	4,59	0	0	195	5.85	0	0
28	0.84	0	4.151	70	2.1	0	0	112	3.36	0	0	154	4.62	0	0	196	5.88	٥	0
29	0.87	٥	1.484	71	2.13	0	0	113	3.39	0	0	155	4.65	0	0	197	5.91	0	0
30		0	0.2	72	2.16	0	٥	114	1	٥	0	156	1	0	٥	198		0	0
3.		0	0	73		0	0	115	1	0	0	157		٥	٥	199		0	0
33	1	0	٥	74		0	0	118	1	0	0	158	1	0	0	200	6	0	0
3:		٥	0	75	1	0	0	117		0	0	159	1	0	0	1		1	
3	1	0	0	76		0	0	118		0	0	160		0	0				
3:		0	0	77	1	0	0	118		0	0	161		0	0	1		1	
3	1	0	0	78		0	0	120		"	0	163	1	"	0	1	1	1	1
3			0	80	1	"	"	12		"	"	164		0	,	1	1	1	
3	1	1 %	"	8		"	"	12	i	1 0	1 0	16	1	l ő	"		1	1	
14	1	"	"	8:		"	"	12			"	160						1	1
4		0		8		0	0	12	1	0	0	16		0	0	1			
4		1 -	0	8			0	12	ı		٥	16			0		1		



Beamwidth angle beta (degrees):

Great circle distance I (km):

Elevation angle phi (degrees):

Number of knots inside the scattering volume n:

Operating frequency (MHz):

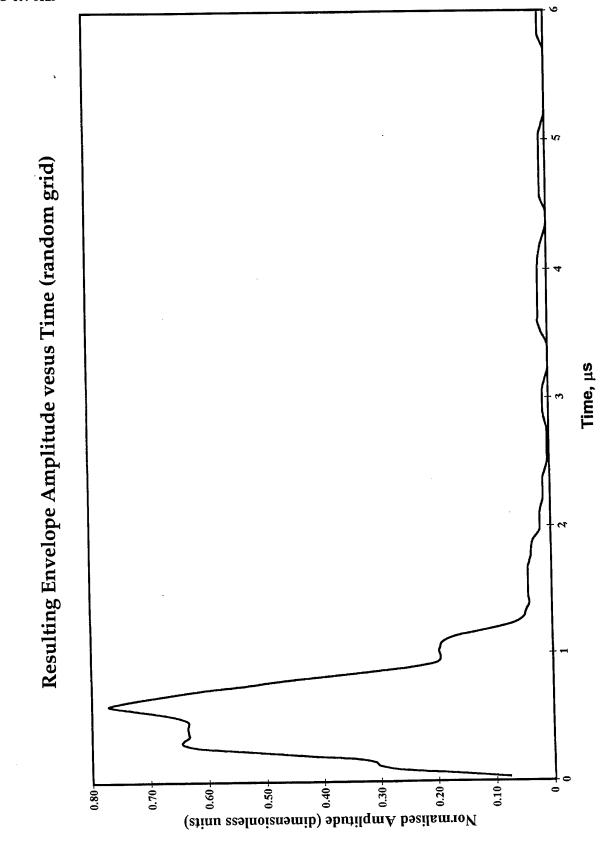
Pulse rise time (µs):

Pulse width (µs):

Pulse fall time (µs):

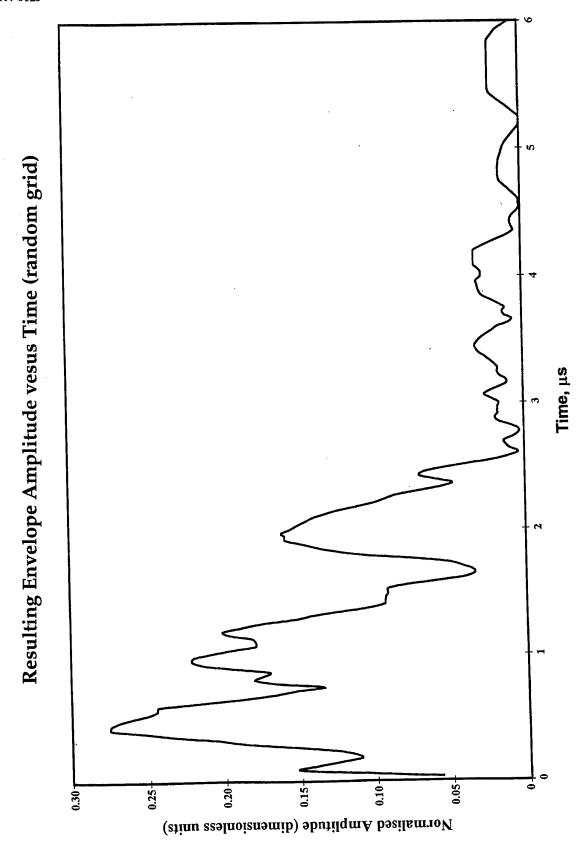
O.15

_				. 1					T 17		plitude	1	Time[i]	Δ	plitude	,	Time[i]	Am	plitude
i	Time[i]	1	plitude		Time[i]		plitude	i	Time[i]			ļ '	titueții		rary units)	.			rary units)
	ļ	\vdash	rary units)	ll			rary units)			initial	rary units) Resulting			Initial	Resulting			Initial	Resulting
_		Initial	Resulting	-	4.00	Initial	Resulting 12.628	85	2.55	ınıua:	0	127	3.81	0	0	169	5.07	0	0
1	0.03	0.3	1.055 2.412	43 44	1.29	0	10.248	86	2.55	0	0	128	3.84	0	0	170	5.1	0	0
3	0.09	0.6	4.094	45	1.35	0	7.891	87	2.61	0	0	129	3.87	0	0	171	5.13	0	0
4	0.03	1	8.946	46	1.38	0	6.667	88	2.64	0	0	130	3.9	0	0	172	5.16	0	0
5	0.15	1	13.161	47	1,41	0	5.317	89	2.67	0	0	131	3.93	0	0	173	5.19	0	0
6	0.18		17.091	48	1.44	0	3,978	90	2.7	0	0	132	3.96	o	0	174	5.22	0	0
7	0.21	1	16.751	49	1.47	0	2.668	91	2.73	0	0	133	3.99	0	0	175	5.25	0	0
8	0.24	1	12.496	50	1.5	0	1.374	92	2.76	0	0	134	4.02	0	0	176	5.28	٥	0
9	0.27	1	10.864	51	1.53	0	0.693	93	2.79	0	0	135	4.05	0	٥	177	5.31	0	0
10	0.3	1	11.494	52	1.56	٥	0.493	94	2.82	0	٥	136	4.08	0.	0	178	5.34	0	0
11	0.33	1	13.042	53	1.59	0	0.293	95	2.85	0	0	137	4.11	0	0	179	5.37	0	0
12	0.36	1	13.158	54	1.62	0	0.093	96	2.88	0	0	138	4.14	0	0	180	5.4	0	0
13	1	1	13.967	55	1.65	٥	0	97	2,91	0	0	139	1	0	0	181 182	5.43 5.46	"	"
14	L	1 1	17.627	56	1	0	0	98	2.94	0	0	140	1	0	0	183		0	0
15		1	24,203	57	1.71	0	0	99	2.97	0	0	141	4.23	0	0	184	1	0	0
1	1	1 1	30.908	58	1	0	0	100		"	0	143	l l	"	0	185	1	0	
1		1	36.937 39.337	59 60		"	١	102		"	"	144		0	1 0	186	1	0	0
1	1		40.692	61	1	"	ů	103		١٠		145		0	0	187	5.61	٥	0
2		;	41.491	62	1	0	0	104	ı	0	0	146	1	0	0	188	5.64	0	0
2			39.367	63	1	•		10	1	0		143	4.41	0	0	189	5.67	0	0
2		1	38.169	64		0	0	10	3,18	0		14	3 4.44	0	0	190	5.7	0	0
2			37.601	65	1.95	0	0	10	7 3.21	0	0	14	4.47	0	0	19	5.73	0	0
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12	5 0.75	0	42.72	67	2.01	0	0	10	9 3.27	0	0	15	1 4.53	0	0	19		0	0
12	6 0.78	3 0	45.483	68	3 2.04	0	0	11	0 3.3	0	0	15	1	١ ۰	0	19	1	0	0
12	27 0.81	ı o	47.33	69	2.07	0	0	11	1	0	0	15	1	0	0	19		0	0
12	28 0.84	1 0	46.909	70		0	0	11		0	0	15	1	- 1	0	19		0	0
•	0.8	1	44.501	7	1	0	0	11	1	0	0	15			0	19	1	1	"
	30 0.9		41.046	7:	1	- 1	0	11	- 1	0	0	15		0	0	19			"
	31 0.93		37.939	7:		1	0	11	1	0	0	15	1	- 1	l ő	20	1	١٠	•
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L	42 1.2	6 0	15.012	2 8	34 2.52	2. 0	0	1	26 3.78	0	0	1	38 5.0	4 0	0	_L			



Beamwidth angle beta (degrees): 4
Great circle distance I (km): 300
Elevation angle phi (degrees): 2.1
Number of knots inside the scattering volume n: 1000
Operating frequency (MHz): 2830
Pulse rise time (μ s): 0.1
Pulse width (μ s): 0.5
Pulse fall time (μ s): 0.15

Time Amplitude					-							· · · · · ·			۸_	militard a	i	Time[i]	Arr	plitude
1	;	Time[i]	Am	plitude	i	Time[i]	ì	•	ľ	Time[i]	1	" l	i i	Time[i]		·	'	11,110[1]	l .	
1	-		(arbit	rary units)	1		(art	itrary units)	1]	``		1					ļ	<u> </u>	
1	1		Initial	Resulting			Initia	Resulting	<u> </u>		_				_		100	5.07	_	0.832
2 0.06 0.6 0.6 16.812 44 1.32 0 4.398 0 2.89 0 0 1.873 171 5.13 0 1.873 172 5.16 0 0 1.875 172 5.16 0 0 0.875 172 5.16 0 0 0.875 172 5.16 0 0 0.87	1	0.03	0.3	7.796	43	1.29	0	1	11	1 -	ı			Į.	1 1		11			0.632
8	2	0.06	0.6	16.812	44	1.32		1	11	l .			1				n	l .	•	0.432
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5 0.15 1 31.009 47 1.41 0 3.91 99 2.77 0 0.0347 1.32 3.86 0 1.573 174 5.22 0 7 0.21 1 44.845 49 1.47 0 3.998 91 2.73 0 0.347 133 3.99 0 1.573 176 5.22 0 8 0.24 1 53.907 50 1.5 0 3.998 92 2.78 0 0.414 134 4.02 0 1.477 177 5.31 0 10 0.3 1 64.581 52 1.58 0 3.998 96 2.85 0 0.901 137 4.11 0 1.337 179 5.37 0 11 0.35 1 6.52 1.65 0 3.998 96 2.85 0 0.901 137 4.11 0 1.337 179 5.34	4	0.12	1	30.115	!	1	1		11	1			n .	1	1 "		H	1 1		0.032
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Beamwidth angle beta (degrees):

Great circle distance I (km):

Elevation angle phi (degrees):

Number of knots inside the scattering volume n:

Operating frequency (MHz):

Pulse rise time (μs):

Pulse width (μs):

Pulse fall time (μs):

0.15

i	Time	e(i)	Am	plitude	i	Time[i]	_ A	mplitude	1	Time[i]	Ar	nplitude	i	Time(i)	. ^	mplitude	i I	Time[i]	An	plitude
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2	1	.06	0.6	11.228	44	1.32	٥	14.151	86	2.58	٥	1.001	128	3.84	0	2.516	170	5.1	0	0.546
3	٥	.09	0.9	15.123	45	1.35	0	12.421	87	2.61	0	0.398	129	3.87	L.	2.722	171	5.13	٥	0.346
4	0	.12	1	13.946	46	1.38	0	10.485	88	2.64	0	0.923	130		٥	2.815	172	5.16	0	0.146
5	۱ ،	.15	1	12.391	47	1.41	10	9.325	89	2.67	٥	1.181	131	ı	1	2.864	173	5.19	0	0
6	0	.18	1	11.029	48	1.44	0	9.272	90	2.7	٥	1.302	132			2.921	174	5.22 5.25	0	0.017
7	٥	0.21	1	11.398	49	1.47	٥	9.231	91	2.73	0	0.736	133	1		2.634 2.597	175 176	5.28	,	0.317
8	0	0.24	1	12.685	50	1	٥ ا	9.074	92	1	0	0.347	134	1	" I	2.746	177	5.31	0	0.617
9	١ ٥	0.27	1	15.375	51	1.53		9.073	93		0	0.361	13		1	3,031	178		٥	0.921
10	1	0.3	1	18.887	52			7.829	94		0	1.59	13			3.059	178		0	1.289
11	1	0.33	1	20.709	53		- 1	5.798 3.9	96		1 0	1.855	13		1	3.059	180	1		1.58
12	1	0.36	1	23,251	54		- 1	3.314	97			1.67	13			3.059	181	5.43	0	1.873
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Prediction of Radar Pulse Envelope Distortion due to Tropospheric Propagation

Marina Oszerova

(DSTO-TN-0125)

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19. ABSTRACT This project is a part of research into the detection of radar signals at ranges well beyond the							
horizon by exploiting the effect of tropospheric scattering. A result of this work is a program							
written in C language which enables the distortion of the envelope of a given radar pulse, which							
occurs as a result of propagating over any path by tropospheric scattering, to be predicted.							

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